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16. ABSTRACT

Under the SITE Emerging Technology Program, the U.S. Environmental Protection Agency (EPA) is seeking to foster the further development of technologies that have been successfully tested at bench-scale and are now ready for pilot scale testing, prior to field or full scale demonstration. The goal is to ensure that a steady stream of permanent, cost-effective, technologies will be ready for demonstration in the field, thereby increasing the number of viable alternatives available for use in Superfund removal and remedial actions. Under this program EPA can offer technology developers financial assistance of up to $150,000 per year, for up to two years. The program is in its second year with seven projects underway and eight more ready to start pending completion of award actions. The Third Emerging Technology Program Solicitation is open to the receipt of new proposals from July 8, 1989 through September 7, 1989. The purpose of this article is to provide the reader with: (1) an introduction to the Emerging Technology Program, (2) an understanding of how the program operates, (3) a summary of those technologies currently being tested and evaluated under the program, and (4) information on how to apply to the program.

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Under the SITE Emerging Technology Program, the U.S. Environmental Protection Agency is seeking to foster the further development of technologies that have been successfully tested at bench-scale and are now ready for pilot-scale testing, prior to field- or full-scale demonstration. The goal is to ensure that a steady stream of permanent, cost-effective, technologies will be ready for demonstration in the field, thereby increasing the number of viable alternatives available for use in Superfund removal and remedial actions. Under this program, EPA can offer technology developers financial assistance of up to $150,000 per year, for up to two years. The program is in its second year with seven projects underway and eight more ready to start, pending completion of award actions. The Third Emerging Technology Program Solicitation is open to the receipt of new proposals from July 8, 1989 through September 7, 1989. The purpose of this article is to provide the reader with: (1) an introduction to the Emerging Technology Program; (2) an understanding of how the Program operates; (3) a summary of those technologies currently being tested and evaluated under the Program; and (4) information on how to apply to the Program.

The U.S. Environmental Protection Agency is evaluating hazardous waste treatment technologies under the Superfund Innovative Technology Evaluation (SITE) Program. This program is authorized under the Superfund Amendments and Reauthorization Act of 1986 (PL 99-499).[1] The SITE Program offers a mechanism for performing joint technology demonstrations and evaluations of technologies between the private sector and EPA. The overall goal of the SITE Program is to ensure, to the extent possible, that innovative technologies are developed, demonstrated, and made commercially available for the permanent cleanup of Superfund sites. EPA wants to replace reliance on land disposal and removal options wherever this is technically feasible.

The SITE Program consists of two separate technology programs. The first part of the SITE Program, the Demonstration Program, places emphasis on technologies that have been developed to the extent that a field demonstration will lead to commercialization. Technologies selected for demonstration must be either at the final stages of pilot-scale development with hardware available, or fully developed with all equipment constructed and ready for use at waste sites. Under the SITE Demonstration Program, the Developer and EPA participate in a joint project to operate and evaluate a technology. In general, the Developer is required to operate the technology at the selected location while EPA is primarily responsible for the development of a demonstration plan and for all sampling and analytical activities and all reporting.

The second part of the SITE Program, the Emerging Technology Program, is the subject of this article. The Emerging Technology Program seeks to foster the further development of technologies that have been successfully tested at bench- or laboratory-scale by the private sector and are now, or soon will be, ready for pilot-scale testing prior to field- or full-scale demonstration. The goal of the Emerging Technology Program is to ensure that a steady stream of permanent, cost-effective, technologies will be ready for demonstration in the field, thereby increasing the number of viable alternatives available for use in Superfund site removal and remedial actions. Under the Emerging Technology Program, EPA can provide financial assistance to a technology developer. The financial assistance provided can be as much as $150,000 per year for up to two years in order to further test and evaluate the technology through the pilot scale.

The Emerging Technology Program is currently in its second year of operation. Seven technologies are being tested as the result of awards in 1988 (with award for an eighth technology pending). Seven more awards are expected in 1989. The purpose of this article is to provide the reader with: (1) an introduction to the Emerging Technology Program; (2) an understanding of how the Program operates; and (3) a summary of those technologies currently being tested and evaluated under the Program.

Program Operation

Under the Emerging Technology Program, partial funding is provided by EPA because of the financial risk involved with technology commercialization. The availability of EPA-provided resources is particularly important since some technology developers do not have the financial resources available to independently pursue development of their technologies. The instrument for funding technology development under the Emerging Technology Program is the competitively-awarded Cooperative Agreement. Cooperative Agreements are mechanisms by which EPA can enter into jointly-funded projects with technology devel-

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TABLE I. Typical evaluation criteria for preproposals.

Criterion	Points
1. Technical description of the technology	20
2. Description of the proposed project	15
3. Summary of data and results to date	15
4. Estimated resources (funding) needed for the proposed project (including preproposer's share)	15
5. Value of the technology to the Superfund program	15
6. Company and personnel experience	10
7. Company capability to commercialize the technology	10
	100

opers. It is important to note that Cooperative Agreements require cost-sharing on the part of the technology developer.

In order to compete successfully for funding under the Emerging Technology Program, sufficient developmental work must have been completed at the bench or on the laboratory-scale, with documented results, to clearly show that the technology holds promise for pilot-scale studies. A limited amount of additional bench- or laboratory-scale testing may be included during the first year of a project if necessary to better design the pilot-scale study. For purposes of the Emerging Technology Program, "pilot-scale" is that scale of development and testing which occurs between proof-of-concept on the bench or in the laboratory, and the construction of field-scale equipment for actual demonstration. It is very important that each technology show promise for commercialization, but the technology must not already be at the field demonstration stage.

How Technologies are Selected and Funded

Each year between April and June, EPA announces (in the *Commerce Business Daily* and trade journals) its intention to issue a Request for Preproposals (RFP). (A preproposal is a very condensed proposal used for initial evaluation and screening.) Interested technology developers are invited to request the RFP, which specifies how to submit a 10-page preproposal describing their technology and plans for it's commercialization. Then, usually in July, the RFP is sent to all parties who responded to the announcement. This Request for Preproposals is intended to solicit preproposals from the private sector for further testing and evaluation of technologies that show promise in solving the most pressing problems at Superfund sites.

These preproposals are then evaluated by a panel of experts from both within and outside EPA. If the preproposal scores well, based on the preestablished "selection factors" described in the RFP, then the preproposer will be invited to submit a detailed Cooperative Agreement Application for funding consideration. Based on the technical quality of the application (as assessed by both internal and external reviewers), and the amount of cost sharing proposed by the applicant, EPA awards up to $300,000 (a maximum of $150,000 per year over two years) to successful applicants. EPA reviews the project to determine if sufficient progress has been made during the first year to warrant funding for the second year. EPA envisions that at least preliminary results from bench or pilot-scale testing will be available by the end of the first year to assist in making this decision.

The total time required between issuance of the RFP, receipt of preproposals, technical review and evaluation of preproposals, and invitation to submit Cooperative Agreement Applications, is approximately five months. Receipt of Cooperative Agreement Applications, technical review and evaluation of the applications, clarification of any questions arising during the review process, and the final award of financial assistance under a Cooperative Agreement takes an additional five months. Typical evaluation criteria used in the past for preproposals and Cooperative Agreement Applications are shown in Tables I and II.

TABLE II. Typical evaluation criteria for cooperative agreements.

1. Identification of the objectives of the project and what benefits EPA might obtain from it.
2. Comparison of the project with other similar efforts. Identification of any overlap or duplication between the project and on-going or completed projects.
3. Quality of the application with regard to the soundness and/or uniqueness of the approach and the significance of the anticipated results.
4. Qualifications and competency of the staff identified for the project in light of their demonstrated prior performance in the project area, or related project areas.
5. Adequacy of the QA Narrative Statement and whether there are any known uncontrolled factors that would affect the quality of the data.
6. Adequacy of the support offered by the Applicant's organization in terms of general facilities, support personnel and services, library, and specific equipment and/or facilities available to the investigator.
7. Strengths and weaknesses of the Application as related to the probability of the project accomplishing the stated objectives.
8. Recommendation for funding which may be: a) "recommend funding" and why, b) "not recommend funding" and why, and c) "recommend funding with conditions" and specify conditions.

Project Management

Technologies selected for study under the SITE Emerging Technology Program are funded and managed as EPA Cooperative Agreements. Rules and regulations for EPA assistance agreements are generally described in 40 CFR Part 30. The following discussion highlights some of the recipient and EPA responsibilities.

Recipients of awards under this program must provide part of the costs for conducting the project. Although no specific minimum cost sharing is specified, generally successful applicants have offered to cost share in excess of 30 percent. EPA views cost sharing by the applicant as an indication of the applicant's confidence and commitment to the proposed technology. The applicant also generally provides for all of the equipment, facilities, and wastes to be used and provides for disposal of any residues. It is also the applicant's responsibility to comply with all federal, state, and local regulations regarding procurement, storage, testing, and disposal of hazardous or toxic wastes. The applicant must also agree to comply with EPA quality assurance/quality control (QA/QC) requirements covering such items as sampling methods, analytical techniques, spikes, replicates, blanks, and the preparation of a Quality Assurance Project Plan for EPA review and approval prior to commencing the study. The recipients must also provide EPA with Quarterly Project Reports (not published) and an acceptable final report suitable for publication in accordance with EPA guidelines.

EPA can provide funding assistance of up to $150,000 per year for each of two years to complete the study. A decision on funding for the second year will be made after reviewing accomplishments made during the first year. EPA manages the project through an experienced Project Officer who will provide administrative and technical guidance to the recipient as well as insure that the project conforms with program goals. The EPA Project Officer will direct the project through both verbal and written instructions as well

TABLE III. Technologies being evaluated under the Emerging Technology Program E01 Solicitation.

Developer	Technology	Technology contact	EPA project manager	Waste media	Applicable waste	
					Inorganic	Organic
Atomic Energy of Canada Ltd. Chalk River, Ontario	Selected removal dissolved toxic metals by chemical treatment/ultrafiltration	Leo P. Buckley 613-584-3311	John F. Martin 513-569-7758	Liquid	Specific for heavy metals	X
Battelle Memorial Institute Columbus, OH	Development of the Electro-acoustic Soil Decontamination (ESD) Process	H. S. Muralidhara 614-424-5018	Diana Guzman 513-569-7819	Solid	X	X
Bio-Recovery Systems, Inc. Las Cruces, NM	AlgaSORB: A new technology for removal and recovery of metal ions from groundwaters	Dennis W. Darnall 505-616-5888	Naomi P. Barkley 513-569-7854	Liquid	Specific for heavy metals	NA
Colorado School of Mines Golden, CO	Constructed wetlands-based treatment of degraded waters for toxic metal removal	Thomas Wildeman 303-273-3642	Edward R. Bates 513-569-7774	Liquid	Specific for heavy metals	NA
Energy and Environmental Engineering, Inc. E. Cambridge, MA	Pilot-scale system for the laser stimulated photochemical oxidation of toxic organics in water	James H. Porter 617-666-5500	Ronald F. Lewis 513-569-7856	Liquid	NA	X
Harmon Environmental Services Inc. Auburn, AL	Solvent washing of contaminated soils	William Webster 205-821-9250	Jackson Hubbard 513-569-7507	Solid	NA	Specific for high molecular weight organics
Western Research Institute Laramie, WY	Contained recovery of oily wastes—CROW	Wesley E. Barnes 307-721-2011	Eugene E. Harris 513-569-7862	Solid	NA	Specific for high molecular weight organics
Membrane Technology and Research, Inc. Menlo Park, CA[a]	Membrane separation of volatile organics from air streams	Hans Witmans 415-328-2228	Paul de Percin 513-569-7797	Gas	NA	Volatile organics

NA = Not Applicable.
X = Applicable.
[a] Award pending.

as periodic visits to the recipient's test facility. At the conclusion of the project, EPA will review the final project report and after any necessary changes are made by the recipient, will approve the final report for publication.

Current Technologies

The first solicitation for the Emerging Technology Program was announced in September 1987. The Request for Preproposals (RFP SITE-E01) was issued in November with a closing date in December 1987. Eighty-four preproposals were received and fifteen applicants were invited to submit Cooperative Agreement Applications. Seven Cooperative Agreements were awarded in September of 1988, and an eighth award is pending. A summary of the successful applicants and their technologies is provided in Table III. A more detailed description of each technology is provided in a later section of this paper.

The second solicitation was announced in March 1988. The Request for Preproposals (RFP SITE-E02) was issued in July with a closing date in September 1988. Sixty-one preproposals were received and seventeen applicants were invited to submit Cooperative Agreement applications. Of the seventeen applications, seven have been recommended for funding pending completion of all Cooperative Agreement requirements. A summary of these technologies is provided in Table IV. More information on technologies selected for award under RFP SITE-E02 will be available following completion of award actions.

As can be seen from examination of Tables III and IV, a variety of technologies and recipient organizations have received, or have been recommended to receive, awards under the Emerging Technology Program. Additional information on technologies in EPA's SITE Program is available in the EPA report entitled "The Superfund Innovative Technology Evaluation Program: Technology Profiles."[2]

Seven Technologies Receiving Awards Under the First (E01) Solicitation

Ultrafiltration with Chemical Treatment—Atomic Energy of Canada, Ltd. This combination of chemical-ultrafiltration treatment is intended for use on toxic metals in groundwater. The process creates two streams: permeate and retentate (Figure 1). Permeate, the bulk of the treated water, is cleaned and released without further processing. The retentate which constitutes less than 5 percent of the feed volume, requires further attention. The retentate contains the separated heavy metal ions and can be handled in a couple of ways. It may be solidified to prevent the release of toxic metals back to the environment, or it may be recycled through the treatment process for further volume reduction. Eventually,

Table IV. Technologies recommended for award[a] under the E02 solicitation.

Developer	Technology	Technology contact	EPA project manager	Waste media	Applicable waste	
					Inorganic	Organic
Babcock & Wilcox Co. Alliance, OH	Cyclone combustor	Lawrence P. King 216-821-9110	Laurel Staley 513-569-7863	Gas Liquid Solid	Metals fixed in ash	X
Center for Hazardous Materials Research Pittsburgh, PA	Acid extraction	Dennis W. Barshter 412-826-5320	Diana Guzman 513-569-7819	Solid	X	NA
Electro-Pure Systems, Inc. Amherst, NY	A/C electro-coagulation phase separation and removal	Patrick E. Ryan 716-691-2600	Naomi Barkley 513-569-7854	Solid Liquid	X	X
Enviro-Sciences, Inc. Mt. Arlington, NJ	Low energy solvent extraction	Zvi Blank 201-398-8183	Jack Hubbard 513-569-7507	Solid Liquid	NA	X
IT Corporation Knoxville, TN	Batch steam distillation/ metal extraction	Robert D. Fox 615-690-3211	Ron Lewis 513-569-7856	Solid Liquid	X	X
University of Washington Seattle, WA	Adsorptive filtration	Mark M. Benjamin 206-543-7645	Denis Nelson 513-569-7642	Liquid	X	NA
Wastewater Technology Centre Burlington, Ontario	Cross-flow pervaporation	Pierre Cote 416-336-4605	John Martin 513-569-7758	Liquid	NA	X

[a] Awards pending completion of all Cooperative Agreement Requirements.

however, the retentate must be removed for ultimate disposal.

Ultrafiltration can be applied in combination with chemical treatment to selectively remove dissolved metal ions from dilute aqueous solutions. A high molecular weight chelating agent is added to the incoming waste solution to form complexes with the metal ions to be removed.

Usually, each chelating polymer has a marked selectivity for one metal cation or for a group of similar cations. The solution is then processed through an ultrafiltration membrane system that retains the macromolecular complexes (retentate), while allowing uncomplexed ions such as sodium, potassium, calcium, chloride, sulfate, nitrate, etc. to pass through with the filtered water (permeate). The filtered water can be recycled or discharged depending upon the metal removal requirements. A removal efficiency approaching 100 percent can be achieved for metal ions that have been complexed.

Since many of the simple and nontoxic ions are allowed to pass through the membrane, they are not concentrated together with the metal ions. The retentate, which may be solidified for permanent disposal, will have a smaller volume and be more resistant to leaching due to its smaller salt content and the presence of chemicals that retard migration of the toxic metals.

Even though ultrafiltration has been applied exclusively to the removal of colloidal solids and fairly large molecules, this technology may be applicable to separation of toxic heavy metal ions such as arsenic, cadmium, chromium, lead, mercury, selenium, silver and barium (as an in situ formed precipitate) from leachates generated at Superfund sites. Other inorganic and organic materials present as suspended and colloidal solids may also be removed.

In Situ Electroacoustic Soil Decontamination—Battelle, Columbus. The electroacoustic soil decontamination

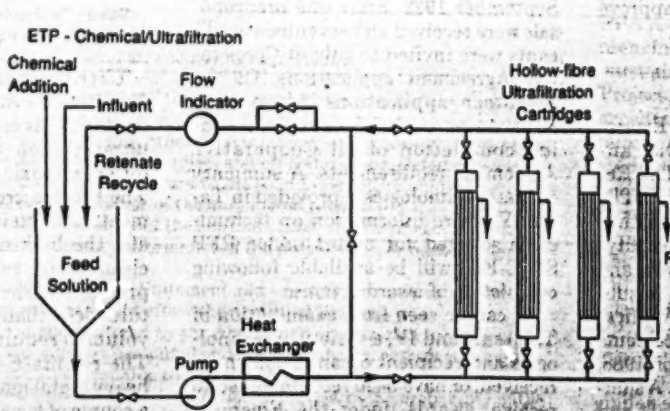

Figure 1. Mobile ultrafiltration unit.

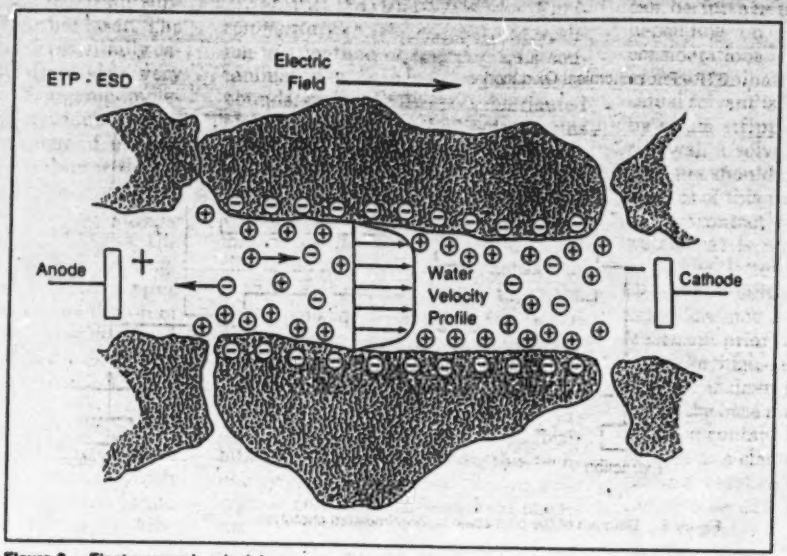

Figure 2. Electroosmosis principle.

(ESD) technology is based on the application of a direct current electric field and an acoustic field to facilitate transport of liquids through soils. The components of this process consist of electrodes, an anode and a cathode, and an acoustic source. Increased transport of liquids through the soil is obtained from the synergistic effect of these two fields.

The double layer boundary theory plays an important role when an electric potential is applied to soils. For soil particles (Figure 2), the double layer consists of a fixed layer of negative ions that are firmly held to the solid phase and a diffuse layer of positive and negative ions that are more loosely held. Application of an electric potential on the double layer results in the displacement of the loosely held ions to their respective electrodes; i.e., the positively charged layer to the cathode and the negatively charged layer to the anode. The ions drag water along with them as they move toward the electrodes.

After the basic mechanism of electro-osmotic transport of water through wet soils under the influence of a direct current occurs, other effects (such as ion exchange, development of pH gradients, electrolysis, gas generation, oxidation and reduction, and heat generation) are produced. The heavy metals present in contaminated soils can be leached out or precipitated out of solution by electrolysis, oxidation and reduction reactions, or ionic migration. The contaminants in the soil may be cations, such as cadium, chromium, lead; and anions, such as cyanide, chromate, and dichromate. Also, the existence of these ions in their respective oxidation states depends upon the local pH and concentration gradients existing in the soil. Application of an electric field is expected to increase the leaching rate and precipitate the respective heavy metals out of solution by establishing appropriate pH and osmotic gradients.

When properly applied in conjunction with an electric field and water flow, an acoustic field enhances dewatering or leaching of wastes such as sludges. The phenomena that augment dewatering of wastes when using the

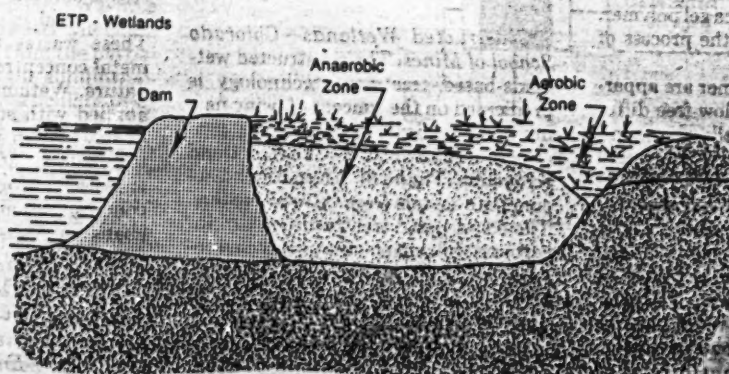

Figure 3. Typical wetland ecosystem.

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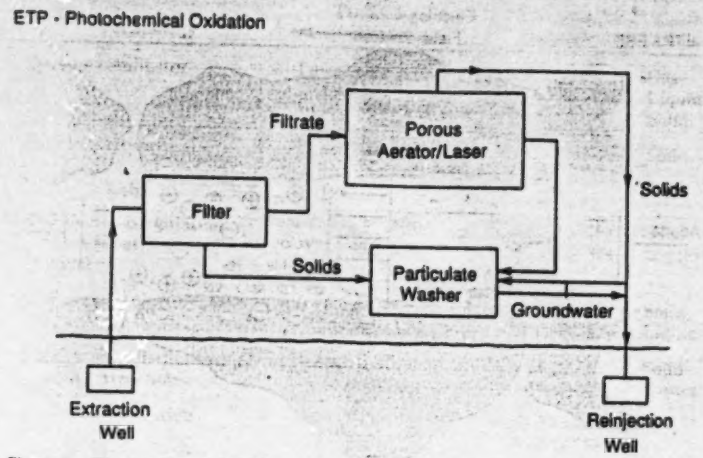

Figure 4. Diagram of the pilot scale laser-stimulated photolysis.

combined technique are not fully understood. Since more contaminated particles are driven to the recovery well, the pores and interstitial spaces can become plugged. Therefore, another potential application of an acoustic field is for clearing the skin in the recovery well.

This technology is intended to be used for in situ cleanup of contaminated soils. Since the technology is dependent upon surface charge, fine grained clay soils are ideal. The technology's potential for improving nonaqueous phase liquid (NAPL) contaminant recovery and heavy metal removal in situ in clay soils could be cost effective for a site remediation if proven practical on the pilot scale.

AlgaSORB—Bio Recovery Systems, Inc. The AlgaSORB sorption process is designed to remove heavy metal ions from aqueous solutions and is based upon the natural, very strong affinity of the cell walls of algae for heavy metal ions. AlgaSORB is comprised of immobilized algal cells in a silica gel polymer. The algae are killed in the process of immobilization.

The pores of the polymer are apparently large enough to allow free diffusion of ions to the algal cells, since similar quantities of metal ions are bound by free and immobilized cells. The immobilization process serves two purposes: (1) it protects the algal cells from decomposition by other microorganisms; and (2) it produces a hard material which can be packed into chromatographic columns, which when pressurized, still exhibit good flow characteristics. AlgaSORB functions as a "biological" ion-exchange resin to bind both metallic cations and metallic oxoanions (large, complex, oxygen-containing ions with a negative charge), but anions such as chlorides or sulfates are only weakly bound or not bound at all. Like ion-exchange resins, the algae-silica system can be recycled. However, in contrast to current ion-exchange technology, the components of hard water (Ca^{2+}, Mg^{+2}) or monovalent cations (Na^{+}, K^{+}) do not significantly interfere with the binding of toxic heavy metal ions to the algae-silica matrix. A prototype portable effluent treatment equipment (PETE) unit, consisting of two columns operated in series, has been developed. Each column contains a quarter cubic foot of AlgaSORB. The unit is capable of treating flows of approximately one gallon per minute. Thus, AlgaSORB, useful for removing metal ions from groundwaters or leachates that are "hard" or contain high levels of dissolved solids, can also be used to remove aluminum, cadmium, chromium, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, silver, uranium, vanadium, and zinc.

Constructed Wetlands—Colorado School of Mines. The constructed wetlands-based treatment technology is predicated on the concept of using natural geochemical and biological processes inherent in a man-made wetland ecosystem (Figure 3) to remove and accumulate metals from influent waters. The constructed treatment system incorporates principal ecosystem components found in wetlands, including organic soils, microbial fauna, algae, and vascular plants.

In the constructed wetlands treatment system, influent waters, which contain high metal concentrations and have low pH, flow through the aerobic and anaerobic zones of the wetland ecosystem. The processes that play a role in the removal of metals by wetlands include filtration, ion exchange, adsorption, absorption accumulation by plants and microbes, and precipitation through geochemical and microbial oxidation and reduction. Metal flocculates and metals that are adsorbed onto fine sediment particles settle out in quiescent ponds, or are filtered out as the water percolates through the soil or the plant canopy. Cation exchange occurs as metals in the water come into contact with humic or other organic substances in the soil medium. Many metals are adsorbed by plants and microbes, and accumulated in their cells. These include lead, copper, nickel, molybdenum, zinc, manganese, iron and aluminum, as well as cyanide, with some retained in portions of the plant tissues after death. Oxidation/reduction reactions that occur in the aerobic/anaerobic zones, respectively, will likely play the major role in removing metals such as hydroxides and sulfides.

The wetlands-based treatment process is suitable for acid mine drainage from metal or coal mining activities. These wastes typically contain high metal concentrations and are acidic in nature. Wetlands treatment has been applied with some success on similar wastewater in the Eastern regions of the United States. However, the differences in geology, terrain, trace metal composition, and climate may require changes in constructed wetlands treatment for mine discharges from metal mining regions of the Western United States.

Laser Stimulated Photochemical Oxidation—Energy and Environmental Engineering, Inc. This technology is designed to photochemically oxidize organic compounds in wastewater into nontoxic compounds through the ap-

plication of ultraviolet radiation supplied by an Argon-Fluorine laser. The photochemical reactor is essentially capable of completely destroying very low concentrations of organic molecules. The process is envisioned as the last step in the treatment of organic contamination in groundwater drawn from a hazardous waste site or of industrial wastewater prior to discharge to the environment. In this process, the energy absorbed is sufficient to fragment the aromatic ring of an organic compound promoting the oxidation of the fragments, but the radiation is not absorbed to any significant extent by the water molecules present in the solution.

The process equipment design (10 GPM capacity) consists of a filtration unit and the photolysis reactor which could be scaled up for direct use in the field with hardware components skid-mounted and stationed at a site. The exact makeup of the process will depend on the chemical composition of the groundwater being treated and, therefore, be site specific; i.e., as a pretreatment, precipitation of heavy metals may be required and carbon adsorption also be required, if the water contains high concentrations of organics.

Collected, contaminated groundwater is pumped from a feed well through a filter unit to remove suspended particles (Figure 4). The filtrate is then fed to the photochemical reactor and irradiated. Air is sprayed through the solution in the reactor to maintain the dissolved oxygen required for oxidation of the organic fragments formed by photolysis. The detoxified water (containing daughter products including CO_2, HCl and some volatile organics) is sent to a degassing unit where volatile materials are removed. Part of the detoxified groundwater is reinjected into the ground, and the rest is recycled to wash the particulate matter separated in the filtration unit. This washing procedure may be required since toxic organics in the groundwater will tend to adsorb onto the particulate matter. Washing with detoxified groundwater will cause desorption of organics from the particulate matter, reducing the equilibrium concentration on the particulate matter. The wash water is then combined with the filtrate stream and returned to the photochemical reactor for further destruction of the toxics. The cleaned particulate matter may be disposed.

This technology can be applied to organic contamination of groundwater drawn from a hazardous waste site or to industrial organic-containing wastewaters, prior to discharge to the environment. This process has been demonstrated in the laboratory in the destruction of single and multiple chlorinated benzenes, phenol and benzene.

Solvent Washing—Harmon Environmental Services, Inc. Solvent washing is a method of cleaning soils contaminated with heavy organic compounds, such as PCBs (polychlorinated biphenyls) and chlorodibenzodioxins (dioxins), down to very low levels. This method is based on a patented solvent blend that has successfully removed PCBs from soil down to 2 ppm, which may allow the soil to be placed at the site without containment. The solvent used in soil washing is critical to the success of the system. It should be immiscible with water (so that the water naturally found on the soil will be displaced), and it should be able to cause the breakup of soil clods without grinding or shredding. Because of the flexibility in selecting a solvent, this technology can be tailored to remove most organic constituents from solid matrices.

Solvent washing is a simple process analogous to the dry-cleaning of clothing (Figure 5). The contaminated solid is mixed with a solvent in which the organic contaminants are soluble within a soil-solvent contactor. The mixture is agitated for an appropriate length of time (usually one hour), and then the solvent with the dissolved organic contaminant is drawn off. As is normal in a process of this type, a fraction of the solvent containing the dissolved organic contaminant remains with the solid. This is typically removed by subsequent washes until the solid is sufficiently clean to satisfy the requirements of the decontamination. The solvent from each wash goes to a reclamation system, where it is distilled, and the contaminant is concentrated as a still-bottom. The still-bottom, a small fraction of the volume of the original soil and a pumpable liquid, can be further treated off- or on-site depending on economics and other considerations. Once the desired level of decontamination is achieved, the residual solvent is removed from the soil by steam stripping. To facilitate this removal, a solvent with a high vapor pressure should be used. Aqueous discharges of this process are also limited to non-contact cooling water and the water that is initially present in the soil. The latter discharge is a very clean, low volume material, which typically does not require any additional treatment prior to discharge.

Unlike high-temperature processes such as incineration, this technology leaves the base matrix unchanged. As a result, a contaminated soil leaves this process as a clean soil suitable for sustaining vegetation. This technology can also be small enough to be "mobile," operates at low temperatures, is totally enclosed (thereby producing virtually no air emissions) and generates very few residuals.

This technology has been shown to successfully clean metal foil, paper and sand, clay soils, high-organic soils, and soils mixed with organic matter (i.e., leaves). It can be applied to contaminated soil laden with heavy organic compounds, especially containing PCBs, tests also have been conducted which show that the technology can remove chlorodibenzofurans and most types of petroleum products and oils from soil.

CROW—Contained Recovery of Oily Wastes—Western Research Institute. The Contained Recovery of Oily Wastes (CROW) process uses an enhanced oil recovery technology, presently used for secondary petro-

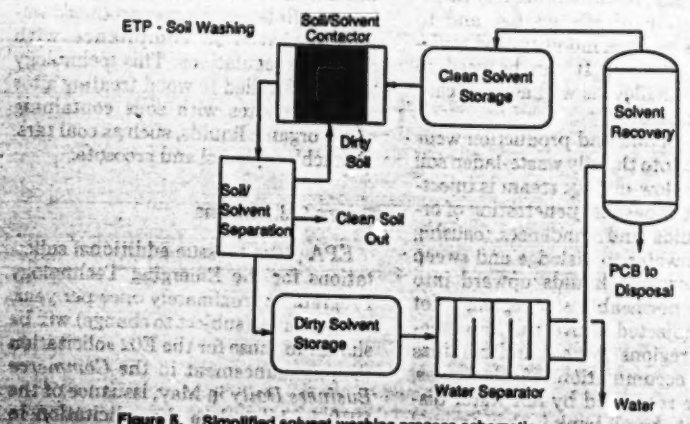

Figure 5. Simplified solvent washing process schematic.

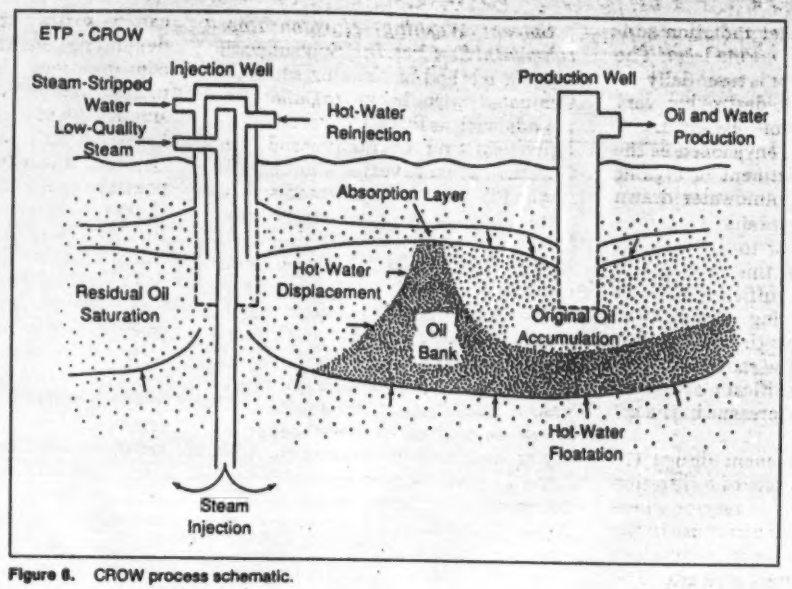

Figure 6. CROW process schematic.

leum recovery and for primary production of heavy oil and tar sand bitumen. This technology employs the same mobile equipment as required by conventional petroleum production technology. In this process, oily wastes in contaminated soil are contained by using steam and hot water displacement to move the accumulated oily wastes and water to above ground treatment. However, even though no single conventional technology can both contain and clean up dense organic liquids at hazardous waste sites, this technology appears to remove a large portion of oily waste accumulations in situ, to stop downward migration of organic contaminants, to immobilize any residual saturation of oily wastes, and to reduce the volume, mobility, and toxicity of oily wastes. It can be used to remediate shallow as well as deep contaminated areas.

After injection and production wells are drilled into the oily waste-laden soil (Figure 6), low-quality steam is injected below the deepest penetration of organic liquids and condenses, causing rising hot water to dislodge and sweep buoyant organic liquids upward into the more permeable soil regions. Hot water is injected above the impermeable soil regions to heat and mobilize the main accumulations of oily wastes, which are recovered by hot water displacement. An oil bank is then formed because the oily wastes displacement increases the organic liquid saturations in the subsurface pore space. Behind the oil bank, the oil saturation is reduced to an immobile residual saturation in the subsurface pore space. After the hot water injection, the oil bank is then displaced to the production well. The oil and water produce would require further treatment.

Site remediation is completed using in situ biological treatment until groundwater contaminants are no longer detected in any water samples from the site. During these in situ treatments, all mobilized organic liquids and water soluble contaminants are contained within the original boundaries of oily waste accumulations. The subsurface environment is protected because the hazardous materials are contained laterally by groundwater isolation and vertically by organic liquid flotation. Excess produced water is treated in compliance with discharge regulations. This technology could be applied to wood treating sites and other sites with soils containing dense organic liquids, such as coal tars, pentachlorophenol and creosote.

Future Solicitations

EPA plans to issue additional solicitations for the Emerging Technology Program approximately once per year. Target dates (subject to change) will be similar to those for the E02 solicitation (i.e., announcement in the *Commerce Business Daily* in May, issuance of the RFP in July, close the solicitation in September). From the preproposals received, EPA anticipates award of 7 to 10 new Cooperative Agreements each year. Anyone interested in applying under this program should watch the *Commerce Business Daily* for announcements, or write to the following address and request to be placed on the mailing list for the next SITE Emerging Technology Program RFP:

Mr. William Frietsch (MS–479)
U.S. Environmental Protection Agency
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268

The E03 solicitation was announced in the Commerce Business Daily on April 18, 1989. This solicitation is open to receipt of preproposals from July 8 through September 7, 1989.

Of primary interest in the E03 solicitation are technologies that can handle complex mixtures of hazardous organic and inorganic contaminants in sludges and soils by either in situ or surface processes that separate, remove, destroy, detoxify, or stabilize the contaminants or provide for improved solids handling and pretreatment. Examples include:

- Treatment of solids (including soils and sludges) containing both organic and inorganic constituents, or only inorganic constituents.
- Materials handling techniques which improve pretreatment and post treatment operations, including those which separate hazardous from nonhazardous components.
- Low cost methods to treat large columns of soil with relatively low contaminant concentration levels.
- Biological technologies for soils and sludges capable of treating or-

ganic contamination.

- Separation/extraction of low-level radioactive waste material from soils.
- In situ treatment processes for soils which would provide alternatives to long term conventional pump and treat approaches to subsurface remediation.

Technologies that are applicable to problems that exist at only a few Superfund sites will be considered, but are of lesser interest than those applicable to numerous Superfund sites.

References

1. "Superfund Innovative Technology Evaluation (SITE) Strategy and Program Plan," EPA-540/G-86/001, Center for Environmental Research Information, Cincinnati, Ohio, December 1986.
2. "Superfund Innovative Technology Evaluation Program: Technology Profiles," EPA-540/5-88-003, Center for Environmental Research Information, Cincinnati, Ohio, November 1988.

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